# Executive Summary

For the first part of our paper, we were asked to develop a mathematical model to predict changes to the housing supply over the next 50 years in two cities of our choosing, of which we chose Seattle, Washington and Albuquerque, New Mexico. To solve this, we developed a linear model through regressing historical housing supply data across both cities, and determined that it proves weak at accounting for large unforseen events like war, epidemics, or natural disasters while still successfully guiding public policy decisions under the assumption that such instances rarely, if ever, occur.

For the second part of our paper, we are asked to develop a similar model to track the rate of homelessness across both cities. Again, we regressed historical homelessness data to develop a linear model, except in these models, we chose to develop models designed for each city rather than one aggregate model due to the completely different homelessness situations across each city.

Lastly, for the third and final part of our paper, we are asked to develop a model to best aid local governments in developing public policy to combat homelessness. We conclude that, based on our results from part 2, public policy decisions made by Albuquerque will be the most successful, and as such, we chose to mathematically model the effects of their public policy on homelessness populations. From there, we reflected on our model and determined that it, yet again, fails to account for difficult-to-foresee situations but serves well as a general guideline for local governments when developing public policy decisions.

# Observing the United States' Homelessness Crisis through Mathematical Methods

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# Contents

# 1 Introduction

Understanding the housing shortage has become more important than ever, as rates of homelessness have reached unprecedented and potentially dire level[1]. Moving into the future, it is undeniably critical for promoting the general welfare of United States populations to best understand housing for influencing public policy across major cities in the United States. Thus, we have prepared the following mathematical models to best understand such a trend.

# 2 It was the Best of Times

## 2.1 Restatement of the Problem

The first problem asks us to develop a mathematical model to predict changes to the housing supply over the next 50 years in two cities of our choosing: Seattle, Washington; and Albuquerque, New Mexico.

## 2.2 Assumptions and Justifications

*There will be no immense, drastic, and long-term permanent changes to housing production possibility within the next fifty years.*

Justification: Events that will drastically change the ability to produce housing, such as immense wars or widespread natural disasters, are neigh-impossible to detect accurately with a simple mathematical model. The only events that can be accurately tracked through mathematical means over short periods of time are cyclical events, like economic recessions or inflation.

*Occupied housing will not be considered part of the available total housing supply.*

Justification: In regards to fixing the homelessness crisis, housing that can be considered available for allocation to unhoused people inherently must be unoccupied by others.

*Differences in median housing costs and median income per capita across regions in both Albuquerque and Seattle will not be considered in determining housing availability.*

Justification: These factors hold a strong correlation with housing unavailability, yet we assume them to have no causal relationship.

## 2.3 Model Development

For our housing availability model, we choose to use a simple vector machine that regresses historical housing availiability data for both Albuquerque and Seat-

tle, and from there, we cross-reference this data with historical economic trends across the United States to best model housing availability over time given cyclical economic trends.
To begin, we trained the model on the following datasets for housing availability in Albuquerque and Seattle and the national GDP of the United States.

| Year | Total housing units | Occupied units | Vacant units |
|---|---|---|---|
| 2010 | 234,891 | 217,256 | 17,635 |
| 2011 | 237,735 | 220,060 | 17,675 |
| 2012 | 239,718 | 222,584 | 17,134 |
| 2013 | 240,277 | 222,491 | 17,786 |
| 2014 | 240,961 | 222,868 | 18,093 |
| 2015 | 241,326 | 222,098 | 19,228 |
| 2016 | 242,070 | 221,320 | 20,750 |
| 2017 | 243,402 | 221,119 | 22,283 |
| 2018 | 244,382 | 222,748 | 21,634 |
| 2019 | 245,476 | 224,166 | 21,310 |
| 2020 | 247,926 | 229,701 | 18,225 |
| 2021 | 252,924 | 236,191 | 16,733 |
| 2022 | 255,178 | 239,800 | 15,378 |

Table 1: Housing Statistics in Albuquerque, New Mexico [3].

| Year | Total housing units | Occupied units | Vacant units |
|---|---|---|---|
| 2010 | 302,465 | 280,453 | 22,012 |
| 2011 | 304,164 | 282,480 | 21,684 |
| 2012 | 306,694 | 285,476 | 21,218 |
| 2013 | 309,205 | 288,439 | 20,766 |
| 2014 | 311,286 | 290,822 | 20,464 |
| 2015 | 315,950 | 296,633 | 19,317 |
| 2016 | 322,795 | 304,157 | 18,638 |
| 2017 | 334,739 | 314,850 | 19,889 |
| 2018 | 344,503 | 323,446 | 21,057 |
| 2019 | 354,475 | 331,836 | 22,639 |
| 2020 | 367,337 | 344,629 | 22,708 |
| 2021 | 362,809 | 337,361 | 25,448 |
| 2022 | 372,436 | 345,246 | 27,190 |

Table 2: Housing Statistics in Seattle, Washington [4].

Due to the limited size of the dataset, we chose to use a $C$ value for our SVM closer to 1.0 to prevent overfitting or underfitting of the data.

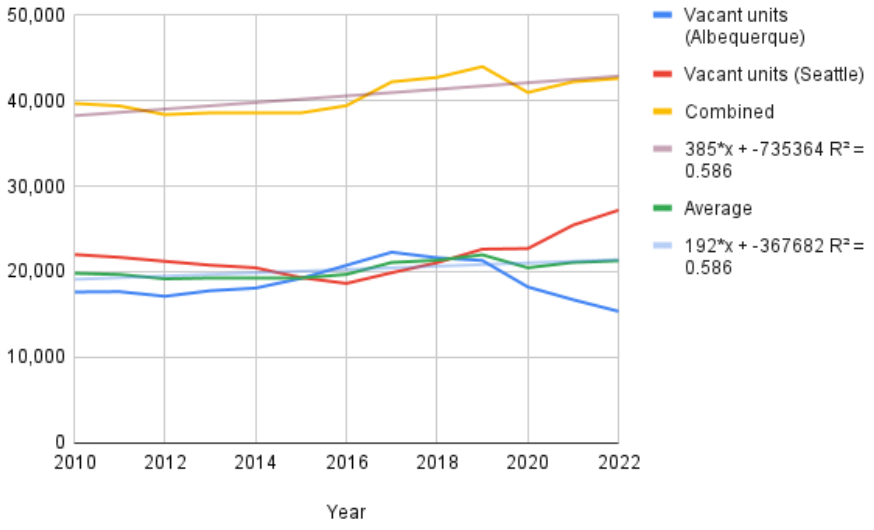


Figure 1: The number of vacancies in Albuquerque and Seattle from 2010 to 2022 [3, 4].

Let $H(x)$ equal the number of available houses for a given year, where $x$ is the current year (absolute from year 0, such as 2024). Simple regression on this dataset results in a total trendline of

$$H_{\text{TOTAL}}(x) = 385x - 735,364$$

where $R^2_{\text{TOTAL}} = 0.586$, and an average trendline of

$$H_{\text{AVG}}(x) = 192x - 367,682$$

where $R^2_{\text{AVG}} = 0.586$.

A coefficient of determination of $0.586$ is undeniably subpar due to the immense indifficulty in representing vast differences across the trends with linear functions.

## 2.4 Results

With this model, we can predict the following housing statistics for 2034 (10 years in the future), 2044 (20 years in the future), and 2074 (50 years in the future):

| Year | Years from 2024 | Total Available Homes | Average Available Homes in Each City | Change from 2024 |
|---|---|---|---|---|
| 2024 | 0 | 43,876 | 20,926 | 0 |
| 2034 | 10 | 47,726 | 22,846 | 1,920 |
| 2044 | 20 | 51,576 | 24,766 | 1,920 |
| 2074 | 50 | 63,126 | 30,526 | 1,920 |

## 2.5 Reflecting on the Model

Overall, our model proves generally weak at predicting immense, unforseen changes to the economic situation of both cities such as the advent of war, the outbreak of a major epidemic/pandemic, or a large-scale natural disaster. This model is best for serving as a general, aggregate predictor of housing availability based on cyclical economic trends. Our coefficient of determination $R^2$ is certainly low, indicating a lack of accuracy, but this is certainly due to the difficulty of modeling previously-mentioned large-scale events with a linear model.

Altogether, we can conclude that this model's impact serves best as a general guideline for understanding realistic public policy because it is solely based largely on aggregate, cyclical economic factors that can be reasonably relied upon to occur continuously.

# 3 It was the Worst of Times

## 3.1 Restatement of the Problem

The first problem asks us to develop a mathematical model to predict changes to the homeless population over the next 50 years in two cities of our choosing: Seattle, Washington; and Albuquerque, New Mexico.

## 3.2 Assumptions and Justifications

*Public policy regarding homelessness will stay roughly the same throughout the next fifty years.*

Justification: We assume that there will be no significant changes to government policy that would severely change the homeless population, as these immense changes to public policy require immense predictions of political trends beyond the scope of this study.

## 3.3 Model Development

For our model, we used yet another linear support vector machine for simple linear regression at $C = 1.0$ as trained on the following data sets:

| Year | Total Population | Total Homeless |
|---|---|---|
| 2007 | - | 1,276 |
| 2008 | - | 1,276 |
| 2009 | - | 2,002 |
| 2010 | 531,403 | 2,002 |
| 2011 | 539,000 | 1,639 |
| 2012 | 545,083 | 1,431 |
| 2013 | 549,812 | 1,171 |
| 2014 | 553,576 | 1,254 |
| 2015 | 556,092 | 1,287 |
| 2016 | 556,859 | 1,222 |
| 2017 | 556,718 | 1,318 |
| 2018 | 559,202 | 1,340 |
| 2019 | 559,374 | 1,524 |
| 2020 | 560,447 | 1,586 |
| 2021 | 562,336 | 1,567 |
| 2022 | 562,551 | 1,277 |

Table 3: Total Population by Year in Albuquerque [2, 5].

| Year | Total Homeless |
|---|---|

Table 4:

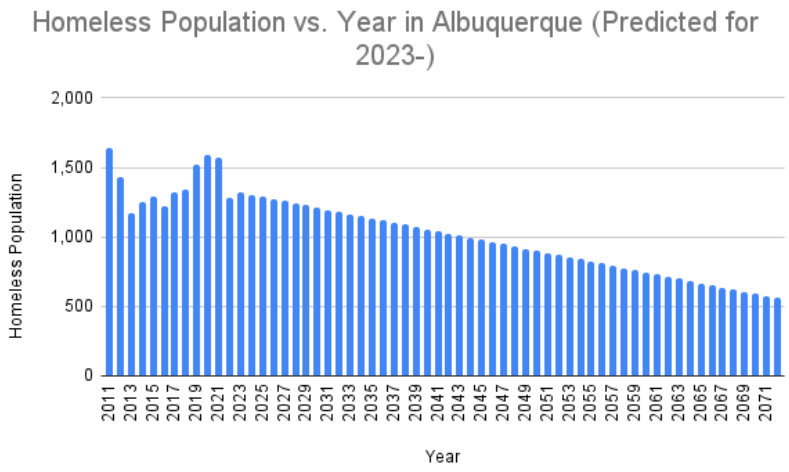


Figure 2: Total Homeless by Year in Albuquerque, New Mexico

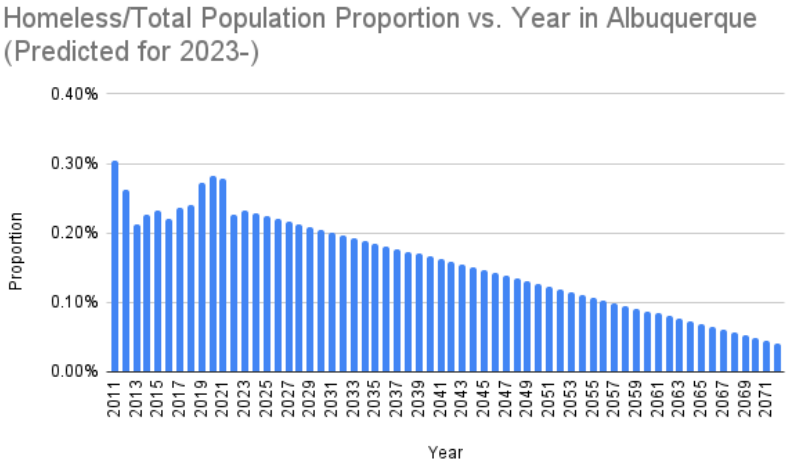


Figure 3: Percentage of the Population that is Homeless in Albuquerque, New Mexico

Therefore, for Albuquerque, let $A_T(x)$ be total number of homeless people in Albequerque, where $x$ is the current year (which is absolute from 0, such as 2024).

$$A_T(x) = 32,757.7 - 15.54(x)$$

Additionally, let $A_{\%}(x)$ be the percentage of Albuquerque's population that is homeless, where $x$ is the current year (which is absolute from 0, such as 2024).

$$A_{\%}(x) = .08124 - 3.9(x) \times 10^{-5}$$

| Year | Total Population | Total Homeless |
|---|---|---|
| 2007 | - | 7,902 |
| 2008 | - | 8,501 |
| 2009 | - | 8,952 |
| 2010 | 595,240 | 9,022 |
| 2011 | 603,174 | 8,972 |
| 2012 | 612,916 | 8,899 |
| 2013 | 624,681 | 9,106 |
| 2014 | 637,850 | 8,949 |
| 2015 | 653,017 | 10,122 |
| 2016 | 668,849 | 10,730 |
| 2017 | 688,245 | 11,643 |
| 2018 | 708,823 | 12,112 |
| 2019 | 724,305 | 11,199 |
| 2020 | 741,251 | 11,751 |
| 2021 | 726,054 | 5,183 |
| 2022 | 734,603 | 13,368 |

Table 5: Total Population by Year in Seattle [2, 5].


Figure 4: Total Homeless by Year in Seattle, Washington

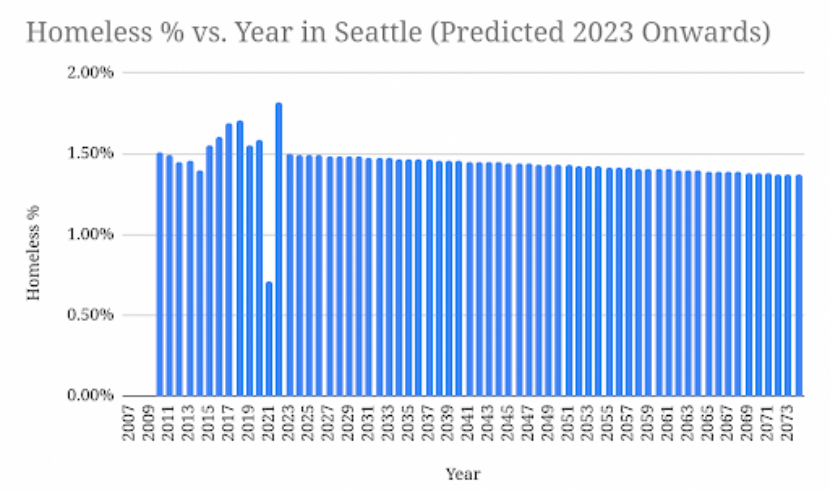


Figure 5: Percentage of the Population that is Homeless in Seattle, Washington

Therefore, for Seattle, let $S_T(x)$ be total number of homeless people in Seattle, where $x$ is the current year (which is absolute from 0, such as 2024).

$$S_T(x) = 341.625x + 7902$$

Additionally, let $S_{\%}(x)$ be the percentage of Seattle's population that is homeless, where $x$ is the current year (which is absolute from 0, such as 2024).

$$S_{\%}(x) = 0.65 - 2.473(x) \times 10^{-5}$$

## 3.4 Results

With this model, we can predict the following homelessness statistics for 2034 (10 years in the future), 2044 (20 years in the future), and 2074 (50 years in the future):

### 3.4.1 Albuquerque, New Mexico

| Year | Years from 2024 | Homeless Percentage | Total Homeless | Change from 2024 |
|---|---|---|---|---|
| 2024 | 0 | $2.304 \times 10^{-3}$ | $1,304.74$ | $0$ |
| 2034 | 10 | $1.914 \times 10^{-3}$ | $1,149.34$ | $-155.4$ |
| 2044 | 20 | $1.524 \times 10^{-3}$ | $993.94$ | $-155.4$ |
| 2074 | 50 | $3.54 \times 10^{-3}$ | $527.74$ | $-155.4$ |

### 3.4.2 Seattle, Washington

| Year | Years from 2024 | Homeless Percentage | Total Homeless | Change from 2024 |
|---|---|---|---|---|
| 2024 | 0 | $0.6$ | $699,351$ | $0$ |
| 2034 | 10 | $0.6$ | $702,767.25$ | $3,416.25$ |
| 2044 | 20 | $0.6$ | $706,183.5$ | $3,416.5$ |
| 2074 | 50 | $0.599$ | $716,432.25$ | $10,249$ |

## 3.5 Reflecting on the Model

Reflecting on the Models: Our homeless models for both the city of Seattle and Albuquerque proves a little weak, as the homeless population rate won't have a linear decrease or increase following the year 2023, but will have its ups and downs. Although our data for the graphs are not perfect, it offers a distinct trend between the two cities, since Seattle's estimated homeless population rate is going up, while Albuquerque's homeless population rate is going down. This gives insight on the effectiveness of Albuquerque's methods in solving the homeless crisis, and should be explored furthermore.

# 4 Rising from this Abyss

## 4.1 Restatement of the Problem

The third and final question asks us to utilize the results from at least one of our previous models to first develop a final model that can be used to best aid a city in combatting the homelessness crisis then analyze the model for its strengths and weaknesses given situations like natural disasters, economic recessions, or migrant populations.

## 4.2 Assumptions and Justifications

*Job availability will be stimulated primarily through public policy from the government.*

The intent of this model is to understand how public policy ought to reflect into homelessness statistics without heavy consideration to external factors, such as the growth or shrinking of privately funded opportunities supplied for homeless people (such as charity or jobs). Such consideration would require more narrow focus on cyclical economic trends, when in reference to the success of implementing simple public policy, such methods would be rendered unnecessary. For the sake of brevity, lawmakers merely need to understand the general impacts of their legislation rather than their impact in context of the entire economic situation of their region.

## 4.3 Model Development

We developed our model based on the predictions outlined in recent public policy decisions made by Albuquerque city officials of combatting homelessness through policy-funded stimulation of job opportunities directly for homeless shelter residents[7]. Given the immense success Albuquerque has had thus far in reducing homelessness year after year (as shown in our previous results), we can conclude that their success in providing conncting opportunities to the homeless ought to serve as the benchmark for determining public policy for addressing homeless populations throughout the nation.

Thus, we developed the following model through our previous linear regression processes with data from Albuquerque's labor statistics [6]. Let $N(x)$ equal our

homelessness population in Albuquerque for a given year, where $x$ is the number of available jobs for the given market.

$$N(x) = 1,368 - 0.037(x)$$

## 4.4 Reflecting on the Model

This model provides a strong general basis for understanding how the availability of jobs for homeless populations within Albequerque serves as an inverse relationship, directly combatting the homelessness crisis in an incredibly effective manner. However, we must acknowledge that it is unreliable in consideration to unforseen events that could divert resources from providing economic opportunities like jobs for the homeless, such as war or natural disasters, due to lacking nuance for accounting for such occurances. Additionally, as a linear model, it will be far less accurate for accounting for cyclical movements in the economy, acting as more of an aggregate measure for combatting homelessness through job opportunities than a guaranteed predictor of homelessness statistics.

# References


[1] Chris Arnold, Robert Benincasa, Jacqueline GaNun, and Haidee Chu. There's a massive housing shortage across the u.s. here's how bad it is where you live. *NPR Economy*, 14 July 2022. Accessed on 3 March 2024 https://www.npr.org/2022/07/14/1109345201/theres-a-massive-housing-shortage-across-the-u-s-heres-how-bad-it-

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[3] U.S. Census Bureau. Selected housing characteristics. U.S. Census Bureau. Accessed on 3 March 2024. https://data.census.gov/table/ACSDP1Y2010.DP04?q=albquerque%20city%20DP04&g=160XX00US5363000.

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